Current Research Journal of Social Sciences 6(1): 28-34, 2014
DOI:10.19026/crjss.6.5563
ISSN: 2041-3238, e-ISSN: 2041-3246

Submitted: October 19, 2013 Accepted: October 30, 2013 Published: January 25, 2014

Research Article

Characterization of Maize Producing Households in Southern Zambia

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Abstract: Maize is an important crop in the livelihood of Zambia's most vulnerable populations. A huge challenge facing most of Sub-Saharan Africa (SSA) countries like Zambia is to increase maize productivity of smallholder farmers, which has remained very low over the past decades. Through various breeding programmes, more than 50 new maize hybrids and open-pollinated varieties have been developed and provided to the farmers through seed companies and Non-Governmental Organizations (NGOs). However, the extent to which such varieties have been adopted remains unknown. The purpose of this study was to characterize the maize producing households and to assess adoption of improved maize varieties. Data were collected from randomly selected households in the maize-producing areas of Monze and Kalomo Districts in southern Zambia. Principal Components Analysis (PCA) on asset ownership was used to generate a wealth index used to rank the survey households. The results confirm that poorly endowed households, most of whom are female-headed, are far less likely to adopt improved varieties than their well-off counterparts. Important maize variety attributes sought by farmers include early maturity (85% of households), tolerance to water stress (83%), yield potential (79%), pest/disease resistance (56%), better processing quality (56%) and cob/grain size (50%). A larger proportion of well endowed households planted improved varieties, compared with their poorly endowed counterparts. These findings suggest that moving the poor households and female-headed households up the wealth ladder poses a considerable challenge and calls for targeting the key factors that could potentially improve their welfare.

Keywords: Maize, improved varieties, Principal Components Analysis (PCA), technology adoption, wealth index, Zambia

INTRODUCTION

Maize is life to more than 300 million of Africa's most vulnerable populations. It is Africa's most important cereal food crop. A huge challenge facing most of Sub-Saharan Africa (SSA) countries like Zambia is to increase maize productivity of smallholder farmers, which has remained very low over the past decades. Rising maize productivity could improve the competitive position of the crop in both rural and urban markets. Improving the competitive position of maize in Zambia is also justified by the growing recognition of the need for new strategies for developing agriculture in semi-arid areas that are prone to drought. Zambia experiences recurrent droughts, which tend to be severest in agro-ecological region I. Droughts, are overwhelming phenomena to SSA, affecting people's livelihoods, food security and economic development. Effective approaches to combat the devastating impacts of drought are of uttermost importance, more so as the situation is set to become even worse as climate change progresses.

In response to this challenge, the International Maize and Wheat Improvement Center (CIMMYT) and the International Institute of Tropical Agriculture (IITA) have over the past two decades been working with National Agricultural Research Institutes (NARIs) to adapt breeding techniques to sub-Saharan Africa. Through this effort, more than 50 new maize hybrids and open-pollinated varieties have been developed and provided to the farmers through seed companies and Non-Governmental Organizations (NGOs). Varieties that are bred to tolerate drought can produce 20-50% higher yields during drought years than other maize varieties. However, the extent to which such varieties have been adopted remains unknown, even in the drought-prone regions.

This necessitates the need to understand key farmer characteristics that affect new technology adoption. This knowledge is important for designing programmes that are effective at accelerating adoption. Farmers also

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make subjective inter-varietal comparisons of key attributes, which need to be understood and internalized in the design of programmes. Understanding farmer characteristics relevant to technology adoption can contribute to the initial phase of describing the farming systems and clarifying farmer objectives, in addition to providing the relevant baseline information relevant for monitoring progress and impact of maize breeding and technology dissemination programmes.

The purpose of this study was to identify farmer and technology attributes that enhance adoption of improved maize varieties. Principal Components Analysis (PCA) was used to construct an asset wealth index using data on asset ownership. Household characteristics and maize varietal use rates were then compared across wealth strata. To the best of our knowledge, few studies have used principal component analysis to analyze adoption of improved maize varieties in Zambia.

METHODOLOGY

Data and data sources: This study uses data which were collected from Monze and Kalomo districts in Southern Province of Zambia. Monze district is located in agro-ecological region II where annual rainfall averages about 800-1000 mm. Kalomo is also located in agro-ecological region II with a small portion of the district located in agro-ecological zone I. Rainfall averages about 350 mm in agro-ecological zone I (Bunyolo *et al*., 1995; Environmental Council of Zambia, 2000). Both districts, like most other places in the province, have experienced declining rainfall levels during the past two decades (Government of the Republic of Zambia, 2005). The two districts were selected on the basis of their high standing in maize production. Within each district, a two-stage sampling process was used to select the sample households, both using simple random sampling techniques. Specifically, in each district, 10 villages were randomly selected in the first stage, after which 17-18 households were selected from each of the selected villages. A total of 350 households were selected across the two districts, of which 58% were located in Monze District alone. A fully structured questionnaire was used to capture information on a range of indicators related to household livelihood strategies and adoption of improved maize varieties. The survey was administered in August 2007. Data were analyzed using SPSS and Stata.

Computing wealth indices: The livelihoods approach is founded on a belief that people require a range of assets to achieve positive livelihood outcomes. The assets which people or farmers need are the human, natural, physical, financial capital and social capital. Human capital represents the skills, knowledge, ability to labour and good health that together enable people to pursue different livelihood strategies and achieve their livelihood objectives. Natural capital refers to the natural resource stocks from which resource flows and services useful for livelihoods are derived. There is a wide variation in the resources that make up natural capital, from intangible public goods such as the atmosphere and biodiversity to divisible assets used directly for production (trees, land, etc.). Physical capital comprises the basic infrastructure and producer goods needed to support livelihoods. Financial capital denotes the financial resources that people use to achieve their livelihood objectives and hence the credit facilities available to farmers are discussed under financial assets. Social capital refers to the social resources upon which people draw in pursuit of their livelihood objectives. These are developed through networks and connectedness; membership to formalized groups; and relationships of trust, reciprocity and exchanges that facilitate co-operation and may provide the basis for informal safety nets amongst the poor.

Drawing heavily on Langyintuo (2008) and Langyintuo and Mungoma (2008), households' access to capital assets can be analyzed after normalizing their resource endowments and computing wealth indices using Principal Components Analysis (PCA). Households' endowments by given assets vary tremendously making it difficult to compare them on a wealth ranking scale. To compare different forms of assets so that ranking households can be objective, it is necessary to normalize the assets. Normalising households' assets involves constructing indices by rescaling the assets' values to between 0 and 1. The indices are then aggregated to obtain a composite index that is used for ranking the households. Following Filmer and Pritchett (2001), Langyintuo (2008) and Langyintuo and Mungoma (2008), the assets were rescaled as follows:

$$i = \frac{x_l - x_{\min}}{x_{\max} - x_{\min}}$$

where,

i = The index
x_l = The level of the asset
x_{min}, x_{max} = The minimum and maximum values of x, respectively, taken from the actual data collected

Once scaled (or normalised), the indicators can be added together without the element of distortion which would be introduced by widely differing value ranges.

PCA is used to calculate the wealth index of each household based on the normalised indices (Filmer and Pritchett, 1998, 2001; Zeller *et al*., 2006). PCA extracts from a set of variables those few orthogonal linear combinations of the variables that capture the common information most successfully. Intuitively the first principal component of a set of variables is the linear index of all the variables that captures the largest amount of information that is common to all of the

variables. Suppose we have a set of *K* variables, a^*_{1j} to a^*_{Kj}, representing the ownership of *K* assets by household *j*. Principal components starts by specifying each variable normalized by its mean and standard deviation. For example, $a_{1j} = (a^*_{1j} - a^*_1)/s^*_1$, where a^*_1 is the mean of a^*_{1j} across all households and s^*_1 is its standard deviation. These selected variables are expressed as linear combinations of a set of the underlying components for each household *j*:

$$\begin{aligned} a_{1j} &= v_{11}A_{1j} + v_{12}A_{2j} + ... + v_{1K}A_{Kj} \\ &... \qquad \forall j = 1,...,j \\ a_{K1j} &= v_{K1}A_{1j} + v_{K2}A_{2j} + ... + v_{KK}A_{Kj} \end{aligned} \quad (1)$$

where, the *A* refers to the components and *v* the coefficients on each component for each variable (and do not vary across households). The solution for the problem is indeterminate because only the left-hand side of each line is observed. To overcome this indeterminacy, PCA finds the linear combination of the variables with maximum variance, usually the first principal component A_{1j} and then a second linear combination of the variables, orthogonal to the first, with maximum remaining variance and so on. Technically the procedure solves the equations $(R-\lambda I)v_n = 0$ for λ_n and v_n, where R is the matrix of correlations between the scaled variables (the *a*s) and v_n is the vector of coefficients on the *n*th component for each variable. Solving the equation yields the eigenvalues (or characteristic roots) of R, λn and their associated eigenvectors, v_n. The final set of estimates is produced by scaling the v_ns so their squares sum to the total variance.

The "scoring factors" from the model are recovered by inverting the system implied by Eq. (1) and yield a set of estimates for each of the *K* principal components:

$$\begin{aligned} A_{1j} &= f_{11}a_{1j} + f_{12}a_{2j} + ... + f_{1K}a_{Kj} \\ &... \qquad \forall j = 1,...,j \\ A_{K1j} &= f_{K1}a_{1j} + f_{K2}a_{2j} + ... + f_{KK}a_{Kj} \end{aligned} \quad (2)$$

The first principal component, expressed in terms of the original (un-normalized) variables, is therefore an index for each household based on the expression:

$$A_{1j} = f_{11}(a^*_{1j} - a^*_1)/(s^*_1) + ... + f_{1K}(a^*_{Kj} - a^*_K)/(s^*_K) \quad (3)$$

The assigned weights are then used to construct an overall 'wealth index', applying the following equation:

$$W_j = \sum_{i=1}^{k} [b_i(a_{ji} - x_i)]/s_i \quad (4)$$

where,

W_j = A standardized wealth index for each household
b_i = The weights (scores) assigned to the (*k*) variables on the basis of the first principal component
a_{ji} = The value of each household on each of the *k* variables
x_i = The mean of each of the *k* variables
s_i = The standard deviation

A negative index means that, relative to the communities' measure of wealth, the household is poorly endowed and hence worse-off while a positive figure signifies that the household is well-off. A zero value, which is also the sample mean index, implies the household is neither well-off nor worse-off.

RESULTS AND DISCUSSION

Table 1 presents demographic characteristics of the sample households in the two study districts, Kalomo and Monze. These statistics suggest that the majority of the households (82%) in the two study districts are male-headed, which is consistent with province-wide statistics standing at 78% (CSO, 2006). About seventy-nine (79%) of the household heads were married, while another 11% were widowed. The mean age for household heads in Monze and Kalomo Districts was 48 and 43 years, respectively. The estimated mean age of the household heads in the sample was 46 years across the two districts. This is consistent with national statistics, which estimate that 69% of the household

Table 1: Demographic characteristics of sampled households

	District		
	Monze	Kalomo	Whole sample
	Mean		
Household size (members)	5.98 (1-15)	7.10 (1-20)	6.44 (1-20)
Age of household head	47. 8 (21-91)	42.6 (22-78)	45.6 (21-91)
Distribution of household heads in age groups (proportion)			
>= 60 years	0.42 (0-3)	0.24 (0-2)	0.34 (0-3)
16 - 59 years	2.83 (0-8)	3.23 (0-8)	3.00 (0-8)
<= 15 years	3.47 (1-10)	3.77 (1-10)	3.60 (1-10)
Female headed households (%)	22.1	12.3	18
Education level of household head (%)			
Illiterate	15.2	5.5	11.4
Primary education	57.8	50.0	54.6
Secondary	23.0	40.4	30.3
Post-secondary	2.5	2.1	2.3
Adult education	1.5	2.1	1.7
Marital status of household head (%)			
Single	6.4	4.8	5.7
Married	76.0	83.5	79.1
Divorced	2.9	3.5	3.2
Separated	2.0	0	1.2
Widowed	12.7	8.3	10.9

Figures in parenthesis are the ranges; Survey data, 2007

heads are of ages 25 through 49 years (CSO, 2006). Thus, on average and on the basis of their ages, the household heads could be regarded to be potentially productive with capacity to adopt new farming practices. About 89% of the heads had some formal education of which 55% had attained primary school education; 30% had secondary school education; and the rest (4%) had attained post-secondary education and some form of adult education. Some 11% reported having no formal education.

Southern Province is well-known for large household sizes, a fact our results seem to confirm for the two study districts. While nationally an average household has 5.1 members, our sample shows an average household size of 6.4. That is, both districts are characterized by large families with Kalomo having substantially larger household sizes (7.1) than Monze (6.0).

Household characteristics by wealth category: Physical capital or assets comprises the basic infrastructure and producer goods needed to support livelihoods. Infrastructure consists of changes to the physical environment that help people to meet their basic needs and to be more productive while the producer goods are the tools and equipment that people use to function more productively. PCA was performedon 22 indicators of wealth or assets. Eight components were extracted. Following common practice, the first component, which accounted for about 19.6% of the total variance in the 22 indicators, was used to construct the index (Table 2).

The scores assigned to the indicators on component 1 are shown in Table 3. The impact of each variable on the overall index was calculated as the score divided by the standard deviation. When a household moves from0 to 1 on a particular indicator, its score on the overall index is increased by the amount of the 'impact' ratio for that indicator (Langyintuo *et al*., 2005).

A household is characterized as being poor if its wealth index is negative and well-off if it is positive. Based on the wealth index, 63% of the sample households can be characterized as being poor, with an index below zero. The well-off households had a mean wealth index of 1.00 while the poorly endowed ones had a mean wealth index of -0.58 (Fig. 1). More than half (51%) of the households in Monze District were well-endowed, compared to Kalomo's 27%. More than 86% of the female-headed households were poorly endowed, compared to 58% for male-headed households.

A number of livelihood indicators for the households according to the different wealth categories are summarized in Table 4. As expected, well-endowed households own more physical assets and livestock than their poorly endowed counterparts. The farm households in the sample own cattle and most keep some combination of small livestock like goats, pigs, chickens and ducks. The estimated Tropical Livestock Units (TLU) per household averaged about 2.8 for the poorly endowed households and 8.7 for the well endowed households.

Table 2: Total variance explained using principal components extraction method using standardized values of variables

		Extraction sums of squared loadings	
Component	Total	% of Variance	Cumulative %
1	4.302	19.557	19.557
2	1.738	7.902	27.459
3	1.275	5.795	33.254
4	1.241	5.642	38.896
5	1.172	5.329	44.225
6	1.119	5.089	49.314
7	1.078	4.899	54.213
8	1.052	4.783	58.996

Survey data, 20

Table 3: Scoring factors and summary statistics for variables entering the computation of the first principal component

Variable	Mean	S.D.	Score	Impact
Bicycles	0.268	0.227	0.110	0.486
Draft animals	0.123	0.184	0.160	0.870
Ox-drawn plows	0.081	0.116	0.190	1.631
Ox-drawn harrows	0.066	0.153	0.174	1.134
Wheel barrows	0.050	0.160	0.082	0.516
Radios	0.198	0.177	0.107	0.603
Private well	0.023	0.095	0.050	0.527
Cultivator	0.052	0.119	0.179	1.505
Mobile phone	0.062	0.169	0.079	0.466
Farm size	0.020	0.056	0.072	1.284
Cropped land	0.121	0.109	0.121	1.111
Household size	0.339	0.162	0.131	0.807
Value of livestock	0.038	0.084	0.089	1.059
Motor vehicle	0.010	0.080	0.060	0.755
Motorcycle	0.020	0.118	0.033	0.280
Tractor harrow	0.004	0.060	0.001	0.024
Private borehole	0.006	0.076	0.016	0.211
Water pump	0.023	0.150	0.035	0.232
Scotch carts	0.037	0.190	0.071	0.374
Television sets	0.103	0.305	0.094	0.307
Membership to farmer groups	0.504	0.501	0.068	0.135
Access to credit 2005/06	0.109	0.312	0.017	0.055

Survey data, 2007

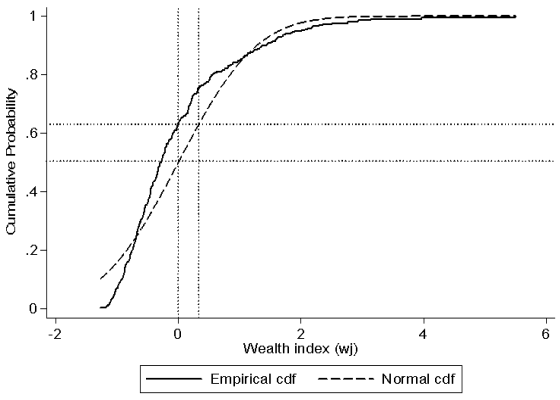

Fig. 1: Distribution of wealth index ranking of households

Table 4: Selected household characteristics by wealth group

Variable	Full sample	Sub-samples[a]	
		Poorly- endowed	Well-endowed
	(1)	(2)	(3)
Number of households	349	220	129
	Mean		
Household size	6.44	5.49	8.06***
Age of the household head (years)	45.6	46.3	44.5
Number of males aged 15-60 years	1.46	1.23	1.84***
Number of females aged 15-60 years	0.78	0.64	1.02***
Farm size in hectares	6.68	4.22	10.88**
Cultivated land area (ha)	3.02	2.22	4.38***
Area under maize (ha)	2.36	1.69	3.50
Number of draft animals	1.60	0.41	3.63***
Tropical livestock units (TLU)	4.96	2.77	8.69***
Value of livestock owned (ZMK)[b]	4,001,312	2,189,139	7,091,840***
	(%)		
Male-headed households	82	75	93***
Households with married heads	79	70	93***
Head reached secondary school	33	26	44***
Most educated: secondary school	47	41	57***
Modern roof on main house	29	22	41***
Households (HHs) receiving credit 2005/06	11	10	13
Households in farmer groups	50	39	70***
Access to extension officers	62	58	71**
Receiving agric input aid in 2005/06	5	5	5
Attending field days in 2005/06	25	24	27
Attending demonstrations in 2005/06	11	11	11

[a]: Mean differences between sub-samples tested by unequal-variance *t* tests; [b]: Exchange rate: 1 USD = ZMK4,100; Significance level: ** = 5%, *** = 1%; Survey data, 2007

Table 5: Maize varieties grown by district and wealth group (%)

Variety	Whole sample	District		Wealth group	
		Monze	Kalomo	Poorly-endowed	Well-endowed
SC513	48.4	36.4	66.1	42.3	44.4
Gankata	14.6	12.4	18.5	14.7	15.4
MRI 534	9.7	10.9	6.5	1.4	7.2
MRI 634	8.4	7.6	9.7	5.7	14.4
MRI 594	7.1	9.8	3.2	6.6	8.2
MRI 514	6.8	9.2	3.2	7.1	6.2
MRI 614	6.8	8.7	4	7.1	6.2
MRI 513	5.5	8.7	0.8	4.7	7.2
Pool 16	4.5	3.3	6.5	6.2	1.0
MRI 734	4.2	3.8	5.8	3.3	6.2
MM 604	3.9	5.4	1.6	2.8	6.2
Obatampa	3.2	1.6	5.6	2.8	4.1
DK 8051	1.9	1.1	3.2	2.4	1.0
MRI 624	1.9	0.5	4	1.9	2.1
MMV 400	1.6	2.2	0.8	1.4	1.0
SC627	1.6	4	-	1.4	2.1
SC621	1.3	2.2	-	-	4.1
MM 603	1	1.6	-	1.4	-
Pan 6243	1	0.5	1.6	0.9	1.0
Pan 599	1	1.6	-	0.5	2.1
SC514	0.9	1.6	-	0.5	1.0
MRI 744	0.6	0.5	0.8	0.5	1.0
Pan 67	0.6	1.1	-	0.5	1.0
Pan 513	0.6	0.5	-	0.5	-
SC403	0.6	-	1.6	0.9	-
MRI 621	0.6	-	1.6	-	2.1
SC709	0.6	-	1.6	0.5	1.0
MRI 694	0.3	0.5	-	0.5	-
MM 601	0.3	0.5	-	0.5	-
Pannar 6363	0.3	0.5	-	-	1.0
SC407	0.3	0.5	-	0.5	-
MMV 600	0.3	0.5	-	0.5	-
Pan 506	0.3	0.5	-	0.5	-
DK8013	0.3	0.5	-	0.5	-
MRI 604	0.3	-	0.8	-	1.0
DK 8010	0.3	-	0.8	0.5	-
MRI 627	0.3	-	0.8	-	1.0
SC613	0.3	-	0.8	0.5	-
Total	143	135.3	153.2	138	153

Survey data, 2007

Table 6: Selected maize production indicators by wealth group

Variable	Full sample	Sub-samples[a]	
		Poorly- endowed	Well-endowed
	(1)	(2)	(3)
Number of households	349	220	129
	Mean		
Cultivated land area (ha)	3.02	2.22	4.38***
Area under maize (ha)	2.36	1.69	3.50
Maize area under improved seed (ha)	1.60	1.14	2.38***
Improved maize seed purchased (kg)	22.7	12.3	40.5*
Basal dressing fertilizer purchased (kg)	109	47	216***
Top dressing fertilizer applied (kg)	108	46	215***
Maize yield (kg/ha)	1,660	1,522	1,894

[a]: Mean differences between sub-samples tested by unequal-variance *t* tests; significance level: * = 10%, *** = 1%; Survey data, 2007

Table 7: Selected maize production indicators by gender of household head

Variable	Full Sample	Gender[a]	
		Female-headed	Male-headed
	(1)	(2)	(3)
Number of households	350	63	287
	Mean		
Cultivated land area (ha)	3.02	2.01	3.25***
Area under maize (ha)	2.37	1.59	2.54***
Maize area under improved seed (ha)	1.61	1.11	1.72***
Improved maize seed purchased (kg)	22.7	10.8	25.3**
Basal dressing fertilizer purchased (kg)	109	61	120***
Top dressing fertilizer applied (kg)	108	60	119***
Maize yield (kg/ha)	1,694	1,412	1,756

[a]: Group-mean difference tests by unequal-variance t tests. Significance: * = 10%, ** = 5%, *** = 1%; Survey data, 2007

Well-endowed households also generally have greater access to social and natural capital than their poorer counterparts. For example, they own more than twice as much land and cultivate twice as much land than their poorly endowed neighbours. They also own nine times more draft animals and three times more livestock in general. Several other indicators seem to confirm the relatively better standing of the well-endowed compared to the poorly endowed households. Well endowed households, for example, are significantly more likely to be male headed, to have married heads, to participate in farmer group meetings and to access extension services (Table 4).

Maize varietal use and production: The survey results show that purchases from seed agro-dealers orseed retail outlets are the major source of seed, accounting for 79%. Other sources include Ministry of Agriculture and Cooperatives (MACO) programmes (8%), non-governmental organizations (NGOs) (5%), cooperatives (2%), own recycled seed (2%), purchases from other farmers (2%), purchases from a seed fair (1%) and free seed from other farmers. Up to three different maize varieties were planted by agricultural households in the 2005/06 agricultural season. As can be seen in Table 5, the maize varieties grown are traditional local varieties, Open Pollinated Varieties (OPVs) and improved hybrid varieties.

The choice of maize variety planted is often influenced by extension staff of the MACO, marketing agents from private seed companies, local agro-dealers or NGOs such as World Vision International and Care International through field days and demonstrations. The most popular hybrid maize varieties planted during the 2005/06 season were SC 513 (48.4%), MRI 534 (9.7%) and MRI 634 (8.4%). Pool 16 is the most popular OPV and was grown by about 5% of the households while Gankata is the most popular local variety and was grown by about 15% of the households (Table 5). In terms of maize varieties planted, a larger proportion of well endowed households planted improved varieties as compared with the poorly endowed households. Household perceptions about the improved maize seed attributes also influenced their decisions on which ones to adopt. Some of the important maize variety attributes sought by farmers include early maturity (85% of households); yield potential (79%), tolerance to water stress (83%), pest/disease resistance (56%), better processing quality (56%) and cob/grain size (50%).

A number of maize production indicators for maize producing households according to the different wealth categories are summarized in Table 6. In terms of various indicators such as maize cultivated area, maize productivity and input use, the households in the well endowed category have significantly larger values than those in the poor category. Similar trends apply to the male headed households compared to the female headed households (Table 7).

CONCLUSION

By characterizing the farm households using Principal Components Analysis (PCA), this study has shown that there is significant differentiation in terms of asset wealth among the maize producing households. By comparison, for most physical assets, the well-endowed households in the sample own more than the poorly endowed households. The mean asset values of the poorly endowed households are smaller than the sample means for the well endowed households. Even in terms of livestock ownership, the well endowed households own more animals than the poorly endowed households. The well endowed households also generally have higher access to social capital as compared to the poorly endowed households. In terms of maize varieties planted, a larger proportion of well endowed households plant improved varieties as compared with those in the poorly endowed households. It is also observed that in terms of the various livelihood activities such as in maize cultivated area, maize productivity and input use, the households in the well endowed category have significantly larger values than those in the poor category. Lastly, a comparison of some of the indicators by gender category shows that the female headed households are less endowed as compared to their male-headed counterparts. The marked differences in assets and technology use between household classes-be it well endowed versus poorly endowed or male-headed versus female-headed-pose considerable challenges to moving the poor households and female-headed households to a relatively wealthier category and calls for targeting the key factors that could potentially improve their wellbeing.

ACKNOWLEDGMENT

This study received financial support from the Drought Tolerant Maize for Africa (DTMA) project which is jointly implemented by CIMMYT and the IITA and is funded by the Bill & Melinda Gates Foundation and the Howard G. Buffett Foundation.

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